EFFECT OF SILVICULTURAL PRACTICE AND VENEER GRADE LAYUP ON SOME MECHANICAL PROPERTIES OF LOBLOLLY PINE LVL

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ABSTRACT

Loblolly pine harvested from silviculturally different stands was used to manufacture 13-ply laminated veneer lumber (LVL). For each stand, LVL was manufactured with either all A-grade or all C-grade veneer. A stand that was managed to quickly produce sawlogs (sudden sawlog) gave the highest strength for A-grade LVL tested in both edgewise and flatwise orientations and C-grade tested in the flatwise orientation. None of the veneer from this stand was obtained from the live crown area and, therefore, was knot-free. Stiffness values did not significantly differ among the stands. The effect of veneer grade arrangement within a panel was also investigated and significant differences were found to exist. The most favorable mechanical properties for veneer grade arrangement were obtained with a layup that placed two A-grade veneers located in the bottom two laminations (tension side) and a single A-grade veneer on the other face (compression side) and a C-grade core. This finding has possible economic implications since some other layups included more A-grade veneer. Several of the groups from both the silvicultural and veneer grade arrangement studies met the mean value design requirements for dense select structural 2- by 4-inch southern yellow pine visually graded lumber.

A constantly increasing global population has led to a greater demand for wood. Many different wood-based composites have been developed to help reduce the demand for solid wood. Products such as plywood, particleboard, and medium density fiberboard provide building materials in much larger and more convenient sizes than solid wood. These panel products are accepted for sheathing purposes. However, many of these wood-based composites lack the necessary strength and stiffness properties required for structural applications. Laminated veneer lumber (LVL) is a wood-based composite that can be an alternative to solid wood for structural applications. LVL provides not only larger and more convenient product sizes but also higher and more reliable engineering properties. LVL is one of the latest of the ever-evolving new types of wood composites; it possesses more reliable strength for design purposes and allows for superior utilization efficiency of our timber resource. LVL possesses many of the critical mechanical properties of lumber and has been researched and commercially produced for several years in the United States.

Early research by Koch showed that a greater mean modulus of elasticity (MOE) and allowable fiber stress can be obtained with 2- by 4-inch southern yellow pine (SYP) LVL compared to sawn lumber of equal dimensions (8,9). Beam strength was found to be optimum with the stiffest veneers on each face (5,8-11). Additional information regarding the effect of butt joints (12) and finger joints (5) is also available.

With regard to SYP silvicultural effects on LVL, Biblis and Carino (5) manufactured 13-ply panels and found a greater MOE and modulus of rupture (MOR) with B-grade veneer from a 50-

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TABLE 1. — Basic stand information mean values of the five harvested loblolly pine trees from the five stands growing near Crossett, Ark.

Stand	Age	Height	DBH[a]	Basal area	Stand index	Live crown ratio[b]
	(yr.)	(ft.)	(in.)	($ft.^2$/acre)		(%)
1 - Sudden sawlog	48	94.2	21.1	90	95	56
2 - Conventional	48	93.8	15.3	118	95	39
3 - Natural	48	98.6	16.4	76	100	39
4 - Single tree	49	88.6	16.4	72	89	55
5 - Crop tree	79	110.2	24.7	42	97	56

[a] Diameter at breast height.
[b] Live crown ratio = {length of live crown/total length of tree} × 100.

TABLE 2. — Effect of forest management on veneer visual grade yields (% yield per grade).[a]

Stand	Veneer grade					
	A	B	Cp	C	D	X
	(%)					
1	3	15.5	9	12.4	50.7	9.4
2	2.5	9.6	10.2	65.7	11.4	0.6
3	16.1	13.9	7.7	35.1	27	0.2
4	14.3	18.6	7.8	47.9	11.4	0
5	9.7	17.7	9.8	21.5	39.8	1.5

[a] Source: Groom and Mullins (7).

year-old stand than from C-grade veneer from a 20-year-old stand. A detailed study by Kretschmann et al. (13) found that SYP and Douglas-fir LVL manufactured with increasing percentages of juvenile wood exhibited an expected decrease in MOR and MOE. Their study showed that LVL of structural integrity can be fabricated with significant percentages of juvenile wood but will consequently lead to products of lower design values than mature wood.

The objectives of our study were not to compare juvenile and mature wood properties but rather to study LVL properties from five silviculturally different SYP stands. Also, this project attempted to determine the optimal placement of different veneer visual grades in an LVL panel. Specifically, our objectives were to 1) determine the effect of silvicultural practice on the MOR and MOE of SYP LVL from five silviculturally different stands; and 2) determine the effect of five different veneer grade layups on MOR and MOE.

MATERIALS AND FABRICATION

Five representative trees each from five silviculturally different loblolly pine (*Pinus taeda* L.) stands growing near Crossett, Ark., were harvested and bucked into peeler bolts (**Table 1**). The grade recovery for each stand on a percentage basis is presented in **Table 2**. All stands are described in detail by Baker and Bishop (3). Three of the silvicultural regimes were even-aged and consisted of stand 1 (sudden sawlog), stand 2 (conventional), and stand 3 (natural regeneration). The sudden sawlog and conventional stands were the only true plantations included in the study. The term sudden sawlog originated at the USDA Forest Service, Crossett Experimental and Demonstration Forest at Crossett, Ark. This term was developed because the goal of a sudden sawlog silvicultural strategy is to produce trees of sawlog dimension as rapidly as possible. The uneven-aged stand investigated was subdivided into two tree age classes, i.e. stand 4 (single tree selection) and stand 5 (crop trees).

The even-aged stands can be described as follows. Stand 1 (sudden sawlog) was harvested at age 48 and was subjected to green pruning and biennial mowing. Stand 2 (conventional) was 48 years old at harvest and was moderately thinned during the juvenile period. It was never pruned or treated for understory control. This stand is typical of many pine stands throughout the South. Stand 3 (natural regeneration) was 47 to 49 years old. These trees were naturally regenerated and were never subjected to thinning, pruning, or understory control.

The mature, uneven-aged site had been under selective management for 50 years. During this time, two age-classes of trees developed. Stand 4 (single-tree selection) included 47- to 51-year-old dominant and codominant trees. Stand 5 (crop trees) was 77 to 85 years old and was harvested from the same stand as the single-tree selection. These two groups are hereafter referred to as separate stands for simplicity even though both were actually growing together. These crop trees had been left uncut by all previous thinning operations and were easily separated from the single tree selection group (stand 4) based on size.

The bolts were rotary-peeled by Hunt Plywood at Pollock, La., to a target thickness of 1/8 inch and clipped to approximately 54 by 98 inches. The veneer was coded according to stand, tree number, and bolt number as it was peeled. The veneer was dried commercially to a moisture content (MC) of 6 to 8 percent, transported to the USDA Forest Service, Southern Research Station in Pineville, La., stored in a controlled environment of 72°F and 36 percent relative humidity (RH), and graded by a grader from APA–The Engineered Wood Association.

For determination of the effect of silvicultural practices, LVL was manufactured from stands 1 through 4, with either all A-grade veneer or all C-grade veneer. For stand 2, some knot-free, B-grade veneer was used in addition to A-grade. Each panel type was replicated four times. Veneer from stand 5 (crop trees) was excluded from the study of the effect of silvicultural practices in order to have sufficient veneer to determine the effect of five different veneer layups on MOR and MOE. The five different veneer grade-based groups produced with veneer from stand 5 (crop trees) are as follows: Group I = AACCCCCCCCCAA; Group II = ACCCACCCACCCA; Group III = AACCCCCCCCCCA; Group IV = ACCCCCACCCCCA; and Group V = AACCCCACCCCAA. All layups were fabricated four times. The veneer from all stands for a particular grade was randomly sampled from the five trees harvested per stand. Veneer was not separated based on peeler bolt position within the trees.

Panel fabrication was accomplished at a Riverwood International plywood mill at Joyce, La. A commercial extended phenolic resin (52% solids) was applied to veneers with a curtain coater at a rate of 92 pounds per 1,000 ft.^{2} of double glueline. The tight side was outermost on both faces of all panels and inner veneers were assembled randomly with respect to tight side and loose side. Two hot-press cycles were used. The panels were prepressed for 5 minutes at 200 psi with no heat. The hot-press conditions were 8 minutes at 340°F and 200 psi. Finished billets were stored at the mill for 10 hours before shipping. The four replicate billets of each specific assembly type were sawn into specimens of approximately 1.5 inch by 3.75 inch by 8 feet. Specimens that showed obvious glueline defects, such as blowout, were discarded along with material in the panel next to the blowout region. Less than 10 percent of the panels displayed glueline blowout to some extent. Although the veneer stacks were covered, the blowouts can largely be attributed to an increase in veneer MC during shipping from the USDA Forest Service laboratory to the Riverwood International plywood mill. Also, the veneer likely increased slightly in moisture at the mill prior to fabrication.

Edgewise bending specimens were cut to 86-inch lengths and tested over an 80-inch span. The edgewise specimens were tested in a four-point manner with equal distance between each point. Flatwise, three-point bending tests were centrally loaded and conducted with 38-inch-long specimens over a 30-inch span. The software package allowed for data to be downloaded and analyzed using a factorial analysis on SAS (15). Tukey's Honest Significant Difference test was employed to determine significance between means. All sample beams were air-dried to an approximate equilibrium MC of 11 percent. The air-dried specimens were stacked for 6 months in a constantly air-conditioned laboratory with lumber stickers every 18 inches to allow for proper airflow. Repeated weightings yielded constant results and indicated that the equilibrium moisture content of most specimens was near 10 to 11 percent. Testing was done in accordance with ASTM D-198 (2). Mechanical properties tests were accomplished using a computer-driven software package on an Instron testing machine with an MTS upgrade. Deflection was measured to the nearest 0.001 inch. After each test, a 6-inch-long sample was cut from outside the failure zone for specific gravity (SG) and moisture content (MC) determination.

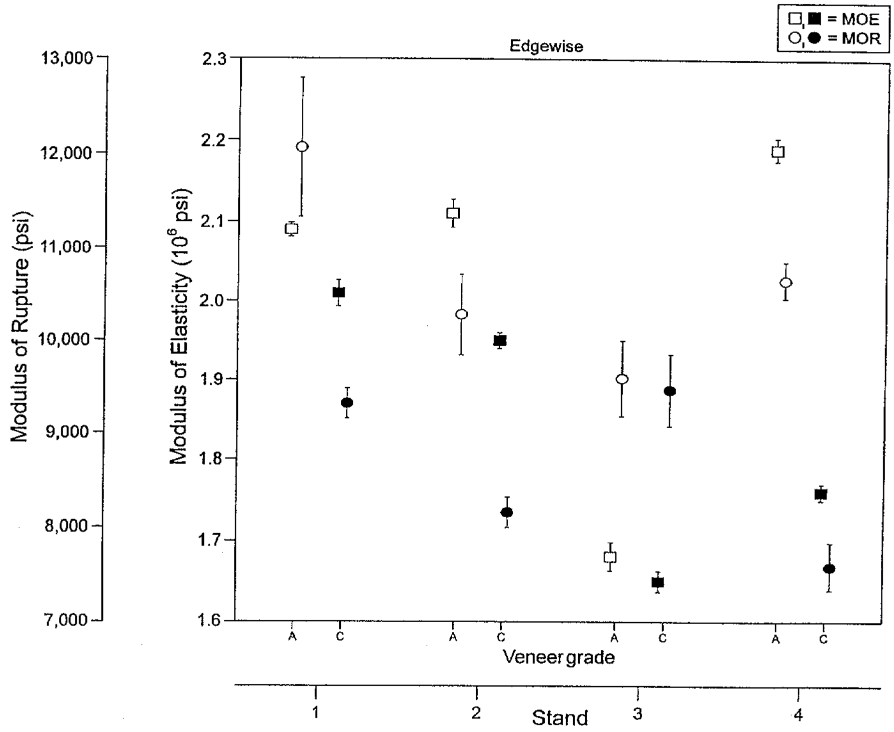

Figure 1. — The effect of four different silvicultural treatments and two different veneer visual grades on edgewise modulus of rupture and modulus of elasticity of 13-ply loblolly pine laminated veneer lumber. The white circles and white squares denote solid A-grade specimens, and the black circles and black squares represent solid C-grade specimens.

RESULTS AND DISCUSSION

EFFECT OF SILVICULTURAL PRACTICE

The effects of silvicultural practice and veneer grade on edgewise MOR and MOE and flatwise MOR and MOE are shown in **Figure 1** and **Figure 2**, respectively. **Table 3** shows the mean MC, SG, and mechanical properties of these specimens. For any specimen group, the number to the left of the dash is the stand number (1, 2, 3, 4, or 5) and the letter to the right of the dash is the veneer visual grades within the panel (A or C).

Results from unpaired t-tests indicate that the MOR in the edgewise orientation of the A-grade panels from stand 1 (1-A) (12,045 psi) is significantly higher than 2-A (10,268 psi), 3-A (9,584 psi), and 4-A (10,631 psi) by 17, 26, and 13 percent, respectively. In the flatwise testing orientation, 1-A (13,751 psi) was significantly higher, respectively, than the mean values obtained from 2-A (9,120 psi), 3-A (10,606 psi), and 4-A (8,638 psi) by 51, 30, and 59 percent, respectively (**Table 4**),. The high strength of LVL made from stand 1 (sudden sawlog) can be partially attributed to the higher specific gravity of these panels (**Table 3**).

A similar trend was observed for the MOR of the C-grade specimens. The edgewise MOR of group 1-C (9,307 psi) was significantly greater than 2-C (8,156 psi) and 4-C (7,595 psi) by 14 and 23 percent, respectively. However, 3-C (9,454 psi) yielded a slightly higher edgewise MOR than 1-C, although not significantly greater. In terms of flatwise MOR, 1-C (10,491 psi) was 52, 22, and 23 percent greater statistically than 2-C (6,887 psi), 3-C (8,587 psi), and 4-C (8,533 psi), respectively. The MOR pattern with regard to the different stands and veneer grade lay-ups is more clearly illustrated in **Figures 1 and 2**. These figures show that in general, stand 1, particularly 1-A, is the most favorable in terms of both flatwise and edgewise MOR; there were few significant differences between the other stands for MOR (**Table 4**).

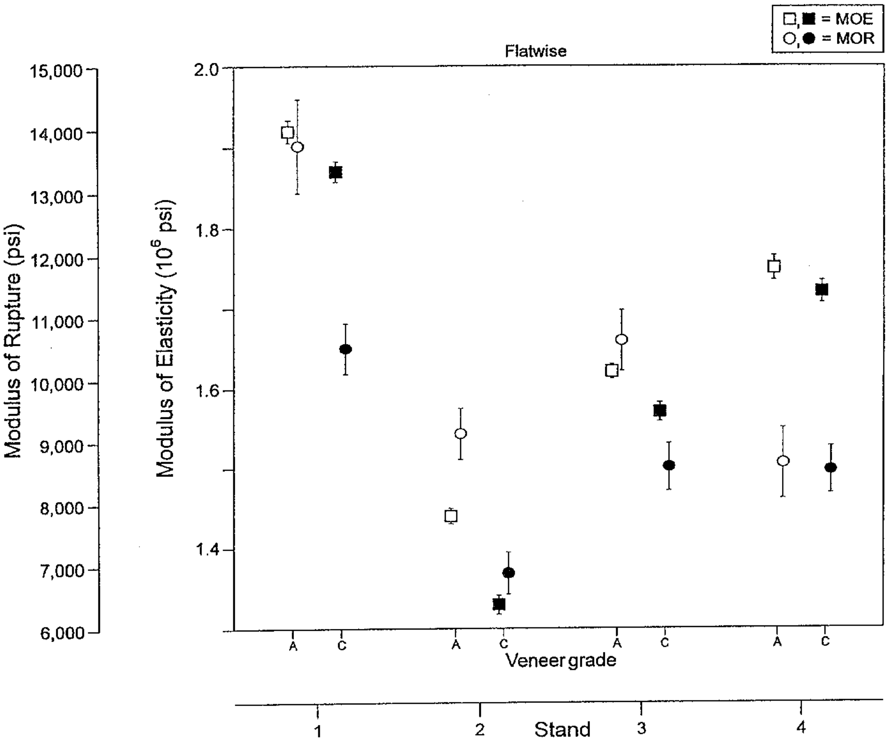

Figure 2. — The effect of four different silvicultural treatments and two different veneer visual grades on flatwise modulus of rupture and modulus of elasticity of 13-ply loblolly pine laminated veneer lumber. The white circles and white squares denote solid A-grade specimens, and the black circles and black squares represent solid C-grade specimens.

When comparing the edgewise and flatwise MOR mean values of the eight silvicultural-grade combinations, on four occasions the mean flatwise MOR was greater than the corresponding mean edgewise MOR (**Figs. 1** and **2**). This can largely be attributed to the ability to cut samples from the 1.5-inch by 3.75-inch by 8-foot beams for flatwise testing that contained visually sound gluelines. Edgewise specimens were tested over a much longer span and therefore had a greater probability of containing areas of lesser glueline integrity. However, in the edgewise orientation, the stress on the gluelines is minimal. Flatwise tested specimens are subject to shear stress development in the gluelines.

It is interesting to note from data in an earlier study on these same stands by Groom and Mullins (7) that all of the A-grade veneer from stand 1 (sudden sawlog) came from the bottom 20 feet of the trees. All of the C-grade veneers were obtained from the area 20- to 30-feet above the stumps. None of the stand 1 (sudden sawlog) veneer came from the live crown area, which is the upper area of the crown that is still alive. The live crown ratio (percentage of total tree height comprised of living branches) for

TABLE 3. — Effect of silvicultural practice and veneer grade on basic mechanical and physical properties of loblolly pine laminated veneer lumber.

Stand-veneer grade[a]	MC[b,d]	SG[c,d]	Edgewise No. of specimens	Edgewise MOR	Edgewise MOE	Flatwise No. of specimens	Flatwise MOR	Flatwise MOE
	(%)			(psi)	($\times 10^6$ psi)		(psi)	($\times 10^6$ psi)
1-A	11.45	0.73	21	12,045	2.09	32	13,751	1.92
	(5.04)[e]	(3.31)		(5.52)	(1.25)		(4.86)	(3.49)
1-C	11.49	0.68	19	9,307	2.01	32	10,491	1.87
	(4.12)	(2.98)		(1.13)	(4.97)		(2.87)	(2.68)
2-A	10.43	0.70	18	10,268	2.11	30	9,120	1.44
	(3.19)	(3.33)		(3.74)	(5.26)		(3.63)	(1.91)
2-C	10.23	0.65	20	8,156	1.95	31	6,887	1.33
	(4.00)	(3.98)		(1.34)	(1.66)		(3.61)	(3.66)
3-A	11.48	0.66	23	9,584	1.68	32	10,606	1.62
	(2.95)	(4.09)		(3.67)	(6.48)		(3.84)	(1.00)
3-C	11.23	0.64	20	9,454	1.65	33	8,587	1.57
	(1.09)	(4.10)		(3.56)	(3.98)		(3.50)	(2.78)
4-A	10.86	0.68	22	10,631	2.19	34	8,638	1.75
	(3.06)	(4.65)		(1.39)	(3.40)		(5.64)	(4.43)
4-C	10.79	0.64	22	7,595	1.76	33	8,533	1.72
	(4.95)	(3.93)		(2.50)	(2.22)		(3.43)	(4.43)

[a] The number to the left of the dash represents the stand and the letter to the right corresponds to panel fabrication with either all A-grade veneer or all C-grade veneers. Stand 1 = sudden sawlog; Stand 2 = conventional; Stand 3 = natural regeneration; Stand 4 = single tree selection.
[b] Moisture content (ovendry basis).
[c] Specific gravity based on volume at 11 percent equilibrium moisture content and ovendry weight.
[d] Represents the mean of 25 samples.
[e] Values in parentheses are coefficients of variation (%).

harvested trees from this stand was 56 percent (**Table 1**).

Stands 2 through 4 had 39, 39, 55, and 56 percent, respectively, live crown ratios. This live crown region is critical for both lumber and veneer because MOR is largely a defect-controlled property, and failure in flexure is largely governed by defects in the tension zone (6). The live crown has many branches and the veneer obtained from this region will be knotty. Therefore, the C-grade LVL from stand 1 was less knotty and consequently stronger than that from the other stands.

MOE, which is slightly more controlled by fibril angle than MOR (4), was less definitive. **Figures 1** and **2** show that A- and C-grade LVL from stands 1 through 4 yielded fairly similar MOE mean values for either edgewise or flatwise testing orientations, respectively. Furthermore, there were no significant differences detected between any of the groups for either testing orientation (**Table 4**). The homogeneity of the MOE data suggests that the 12 stiff gluelines were similar between panels and dominated the flexibility of these 25 layered composites, i.e., 13 veneer sheets and 12 gluelines.

The differences in the edgewise MOE mean comparisons ranged from 1 to 26 percent and from 7 to 41 percent for flatwise (**Table 4**). It is emphasized that the veneer for this study came from peeler bolts located all along the bole. The veneer was not separated by outer, middle, and core regions or by location within the bolts but was grouped according to stand, tree number, and visual grade. Consequently, any of our veneer obtained for either A- or C-grade from any stand will likely have had a wide variation in anatomical properties, such as fibril angle and, therefore, the differences in MOE values between stands are minimal. The pattern of decreasing fibril angle from pith to bark of SYP trees has been well documented by Megraw (14). Biblis and Carino (5) believed that the small differences in MOE values from SYP LVL with different finger-jointing orientation and/or different direction of load application is probably due to the fact that MOE values correspond to relatively smaller stress levels compared to the ultimate stress level at which the MOR values are determined.

The mean values obtained from this study were compared with those required for design purposes of 2- by 4-inch SYP visually graded lumber. Although 1-A (2.09×10^6 psi) and 4-A (2.19×10^6 psi) gave the most favorable results, several other groups yielded mean values sufficient for dense select structural grade design purposes. The poorest LVL groups still made the requirement for No. 1 Nondense (**Table 5**) design values. The evaluation of our mean value with regard to the design requirements of SYP visually graded lumber is for comparative purposes only; no correction has been made for moisture content or variability of test data.

TABLE 4. — Ratio of mean values of laminated veneer lumber groups of differing stands and veneer visual grades.

Comparison[a]	Edgewise		Flatwise	
	MOR	MOE	MOR	MOE
1-A/2-A	1.17*[b]	0.99	1.51*	1.33
1-A/-3A	1.26*	1.24	1.30*	1.19
1-A/4-A	1.13*	0.95	1.59*	1.10
2-A/3-A	1.07	1.26	0.86	0.89
2-A/4-A	0.97	0.96	1.06	0.82
3-A/4-A	0.90	0.77	1.23*	0.93
1-C/2-C	1.14*	1.03	1.52*	1.41
1-C/3-C	0.98	1.22	1.22*	1.19
1-C/4-C	1.23*	1.14	1.23*	1.09
2-C/3-C	0.86*	1.18	0.80	0.85
2-C/4-C	1.07	1.11	0.81	0.77
3-C/4-C	1.24*	0.94	1.01	0.91

[a] Stand 1 = sudden sawlog; Stand 2 = conventional; Stand 3 = natural regeneration; Stand 4 = single tree selection.
[b] * indicates that the comparison is statistically significant at alpha = 0.05.

TABLE 5. — Edgewise design values for 2- to 4-inch-thick by 2- by 4-inch-wide visually graded southern pine lumber and the stand-veneer grade and groups that meet the design value based on edgewise MOE mean value.

Commercial grade	MOE[a]	Stand-veneer grade[b] and groups[c] meeting requirement
	($\times 10^6$ psi)	
Dense select structural	1.9	1-A, 1-C, 2-A, 2-C, 4-A, group II, group III, group IV
Select structural	1.8	group V
Non-dense select structural	1.7	- -
No. 1 Dense	1.8	- -
No. 1	1.7	4-C
No. 1 Non-dense	1.6	3-A, 3-C, group I
No. 2 Dense	1.7	- -
No. 2	1.6	- -
No. 2 Non-dense	1.4	- -
No. 3	1.4	- -
Stud	1.4	- -

[a] Source: American National Standards Institute/National Forest Products Association (1).
[b] Stand 1 = sudden sawlog; Stand 2 = conventional; Stand 3 = natural regeneration; Stand 4 = single tree selection.
[c] Group I = AACCCCCCCCCAA; Group II = ACCCACCCACCCA; Group III = AACCCCCCCCCCA; Group IV = ACCCCCACCCCCA; Group V = AACCCCACCCCAA.

Effect of Veneer Grade Layup

The effect of veneer layup on edgewise and flatwise MOR and MOE of SYP LVL is summarized in **Figure 3** and was done exclusively with veneer from stand 5 (crop trees). **Table 6** summarizes the basic mechanical and physical properties of these five groups, i.e., I, II, III, IV, and V.

No significant differences were detected for edgewise MOR values. This was expected due to the effect of the 12 rigid gluelines in edgewise loading. Group III and group IV gave the highest mean values of 9,850 psi and 9,299 psi, respectively. The mean comparison range was fairly small (0 to 27%) (**Table 7**).

A similar pattern was detected for flatwise MOR with group III (11,806 psi) and group IV (10,483 psi) possessing the largest means (**Fig. 3**). Statistical significance was detected in that group II

(10,128 psi), group III (11,860 psi), and group IV (10,483 psi) were all significantly greater than group V (8,253 psi), which was not statistically different from group I (8,777 psi) (**Table 7**).

Edgewise MOE was the only test in which group III did not yield the highest mean value. Group III (2.00 × 10^6 psi) and group IV (2.02 × 10^6 psi) were both statistically similar to each other and group II (1.90 × 10^6 psi) and group V (1.85 × 10^6 psi) as well. All groups were significantly higher than group V (1.65 × 10^6 psi). Group II, group III, and group IV all met the mean value design requirements for Dense select structural 2- by 4-inch SYP visually graded lumber (**Table 5**).

For flatwise MOE, group III (2.01 × 10^6 psi), group IV (1.75 × 10^6 psi), and group II (1.71 × 10^6 psi) were all statistically similar. Group III was 34 and 16 percent greater than group I and group V, respectively.

These results have many implications. One is that group III, which contained two A-grade veneers on one face and one A-grade veneer on the opposite face, showed the highest mean for all categories except edgewise MOE. Group IV, which had a single A-grade veneer on each face and one in the middle of the panel, gave the highest edgewise MOE and was second for all other categories. These two groups gave much higher values than those of group I and group V, which contained 4 and 5 A-grade veneers, respectively.

A possible financial gain may be realized by using only three A-grade veneers but placing them in a manner similar to group III or group IV. This theory was first proposed by Koch and Bohannan (11), and Koch (8,9). They proposed placing the stiffest laminae in the outer portions and the most limber in the center of the billet. There is little to gain by placing a single A-grade veneer in the middle of the panel as was the case with group IV.

Mechanical properties can be significantly improved by optimal arrangement of A-grade veneer within a panel. It is emphasized that all of the LVL groups for the effect of veneer grade layup study were manufactured with veneer from stand 5 (crop trees).

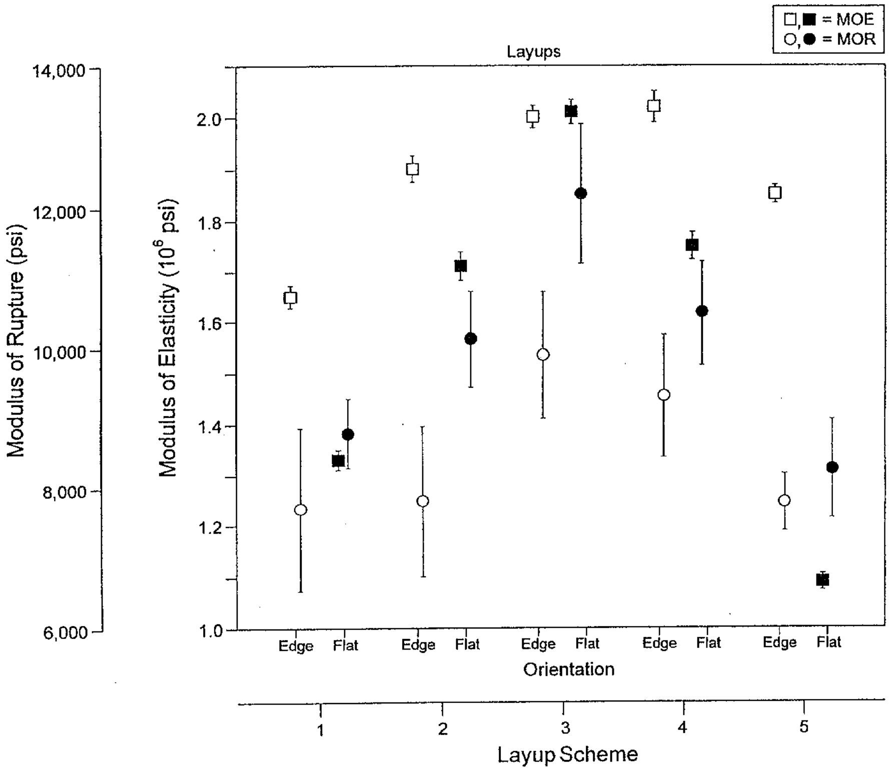

Figure 3. — The effect of five different veneer visual grade layups on edgewise and flatwise modulus of rupture of 13-ply loblolly pine laminated veneer lumber. The white circles and white squares denote edgewise properties, and the black circles and black squares represent flatwise properties.

TABLE 6. — Effect of various veneer grade layups on basic mechanical and physical properties of 13-ply loblolly pine laminated veneer lumber using veneer from stand 5 (crop trees) exclusively.

Group	No. of specimens	MC	SG[a]	Edgewise MOR	Edgewise MOE	Flatwise MOR	Flatwise MOE
		(%)		(psi)	(× 10^6 psi)	(psi)	(× 10^6 psi)
I	Edge - 22	11.7[b]	0.65	7,697	1.65	8,777	1.33
	Flat - 32	(7.68)[c]	(5.59)	(13.92)	(6.48)	(4.53)	(5.35)
II	Edge - 21	11.8	0.64	7,801	1.90	10,128	1.71
	Flat - 32	(7.35)	(3.53)	(12.60)	(7.68)	(5.88)	(9.33)
III[d]	Edge - 24	11.3	0.66	9,850	2.00	11,860	2.01
	Flat - 33	(5.99)	(7.14)	(8.34)	(5.00)	(7.59)	(5.76)
IV	Edge - 23	11.1	0.65	9,299	2.02	10,483	1.75
	Flat - 34	(3.72)	(4.70)	(8.32)	(9.61)	(6.28)	(8.15)
V	Edge - 24	11.6	0.64	7,771	1.85	8,253	1.09
	Flat - 33	(6.04)	(4.25)	(4.18)	(3.24)	(7.51)	(4.34)

[a] Specific gravity based on volume at 11 percent equilibrium moisture content and ovendry weight.
[b] Represents the mean of 11 samples.
[c] Values in parentheses are coefficients of variation (%).
[d] Group III was tested with AA side in compression and A side in tension; all other layups were symmetric with regard to veneer grades within the panel. Group I = AACCCCCCCCCAA; Group II = ACCCACCCACCCA; Group III = AACCCCCCCCCCA; Group IV = ACCCCCACCCCCA; Group V = AACCCCACCCCAA.

Conclusions

Maximum flexural strength and stiffness values were obtained from stand 1, which was managed to produce sawlogs as rapidly as possible (sudden sawlog). All A-grade veneer panels from stand 1 (1-A) gave significantly higher values for edgewise and flatwise MOR, but no significant differences were observed for either edgewise or flatwise MOE. Stands 1 through 4 can be considered statistically similar for MOE. This research has shown that by classifying veneer peeler

TABLE 7. — Ratio of mean values of loblolly pine laminated veneer lumber groups of differing veneer visual grade layups using veneers from stand 5 (crop trees) exclusively.

Group comparison[a]	Edgewise		Flatwise	
	MOR	MOE	MOR	MOE
	(psi)	($\times 10^6$ psi)	(psi)	($\times 10^6$ psi)
I / II	0.99	0.87	0.87	0.78
I / III	0.78	0.83*	0.74	0.66*
I / IV	0.83	0.82*	0.84	0.76
I / V	0.99	0.89	1.06	1.22
II / III	0.79	0.95	0.85	0.85
II / IV	0.84	0.94	0.97	0.98
II / V	1.00	1.03	1.23*	1.57*
III / IV	1.06	0.99	1.13	1.15
III / V	1.27	1.08	1.44*	1.84*
IV / V	1.20	1.09	1.27*	1.61*

[a] Group I = AACCCCCCCCCAA; Group II = ACCCACCCACCCA; Group III = AACCCCCCCCCCA; Group IV = ACCCCCACCCCCA; Group V = AACCCCACCCCAA.
[b] * indicates that the comparison is statistically significant at alpha = 0.05.

logs based on silvicultural growing conditions, superior LVL can be produced that meets the design values for several high grades of 2- by 4-inch SYP lumber.

The highest mechanical properties were generally obtained with a veneer grade layup that placed two A-grade veneers located in the bottom two laminations (tension side) and a single A-grade veneer on the other face (compression side) and a C-grade core (i.e., group III). It was shown that strategic A-grade veneer placement in a panel will influence MOE values but not ultimate bending strength.

Future research is recommended to address the significance of veneer grade layups group III and group IV manufactured from stand 1 (sudden sawlog) instead of stand 5 (crop trees) because of the favorable performance of stand 1 (sudden sawlog) during the study of the effect of silvicultural practice.

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